TEMPORAL AND SPATIAL CHANGES OF CLIMATE ELEMENTS IN HUNGARY

PRECIPITATION

- As the climate of Hungary tends to drought, temporal and spatial distribution of precipitation has of special importance in agriculturala nd ecological point of view.
- Precipitation in Hungary is generally less than the requirement of vegetation. A csapadék általában kevesebb, mint a vegetáció igénye. The climatic water balance is negative in the substantial part of the country.

Mean monthly and annual sums of precipitation
in Hungary, mm, 1961-1990

station	J.	F.	M.	Á.	M.	J.	J.	A.	Sz.	O.	N.	D.	year
M. magyaróvár	36	35	31	40	57	62	57	58	42	40	52	42	552
Keszthely	35	33	41	51	62	79	74	70	51	41	62	43	642
Pécs	39	32	38	55	63	84	61	63	47	37	56	44	619
Budapest-KLFI	32	31	29	38	55	63	52	51	40	33	52	40	516
Kecskemét	27	27	30	41	51	73	51	45	38	31	49	43	506
Szeged	29	25	29	41	51	72	50	57	34	26	41	40	495
Békéscsaba	36	32	37	44	56	80	60	53	36	34	43	49	560
Debrecen	37	30	34	42	59	80	65	61	38	31	45	44	566
Kékestető	49	53	53	64	96	106	77	82	59	62	77	59	837

Temporal dynamics of precipitation

- The annual cozrse of precipitation shows double wave. Minimum precipitation falls in January. This is due to the low vapour pressure and frequent anticyclonic large-scale weather situations (Siberian maximum).
- Most of the precipitation falls between May to July. This may be associated with the maximum vapour pressure, near the Medard cyclone activity, and the intensifying convection.
- Maximum precipitation shows slight temporal delays in different regions of the country.
- In the Transdanubian Hills and the Bakony area the most precipitation occurs in May, in West Hungary in July, while in the major part of the country in June.

Temporal dynamics of precipitation

- A secondary maximum of precipitation can also be observed at autumn (October-November) in South Dunántúl and in the south-east slopes of Dunántúli Medium-high Mountains.
- It comes from the rains of warm fronts of the Mediterranean cyclones (Genoa cyclones) originating from Ligurian sea area.
- It is not uncommon that, due to abundant autumn rains, winter hal-year is wetter (in 20-30% of the cases).
- Greater precipitation of the winter half-year is most specific to the South Dunántúl area showing Mediterranean effects. In Alföldön the summer is wetter in 80-90% of the cases.
- The secondary maximum in autumn is weakening from south-west to north-east direction.
- The annual sum of precipitation may show up to 2.5-fold fluctuations year by year. This is the most variable climatic element.

Mean summer - winter sums of precipitation in Hungary, mm, 1901-1950

station	sum hy	win hy	station	sum hy	win hy
M.magyaróvár	338	256	*Kecskemét*	301	212
Sopron	423	265	*Miskolc*	376	249
Szombathely	438	262	*Szeged*	324	249
Nagykanizsa	443	334	*Szolnok*	302	222
Keszthely	415	285	*Békéscsaba*	328	235
Pécs	385	316	*Debrecen*	342	243
Győr	335	256	*Nyíregyháza*	353	230
Székesfehérvár	322	243	*Kékestető*	460	324
Budapest	331	286			

- In the dryest years 290-350 mm precipitation falls in Alföld area, while in wetter years even 800-900 mm precipitation was measured there. In West-Dunántúl precipitation totals exceeding 1000 mm are not uncommon during these years.
- In any month may occur complete lack of prrecipitation.
- Long-term average of the number of rainy days is around 120 days for the whole, so theoretically every third days is rainy day. (Rainy day: the amount of precipitation reaches at least 0.1 mm.)
- The length of the longest rainy period was 52 days.
- In summer, frewuently occur monthly rainfall amounts of 200-300 mm.
- Since 1870 the biggest annual amount of precipitation was measured at Pécs city (1204 mm) in 1896; while the smallest was at Szeged city (216 mm) in 2000.

The highest annual precipitation amounts
in Hungary, mm, 1881-1992

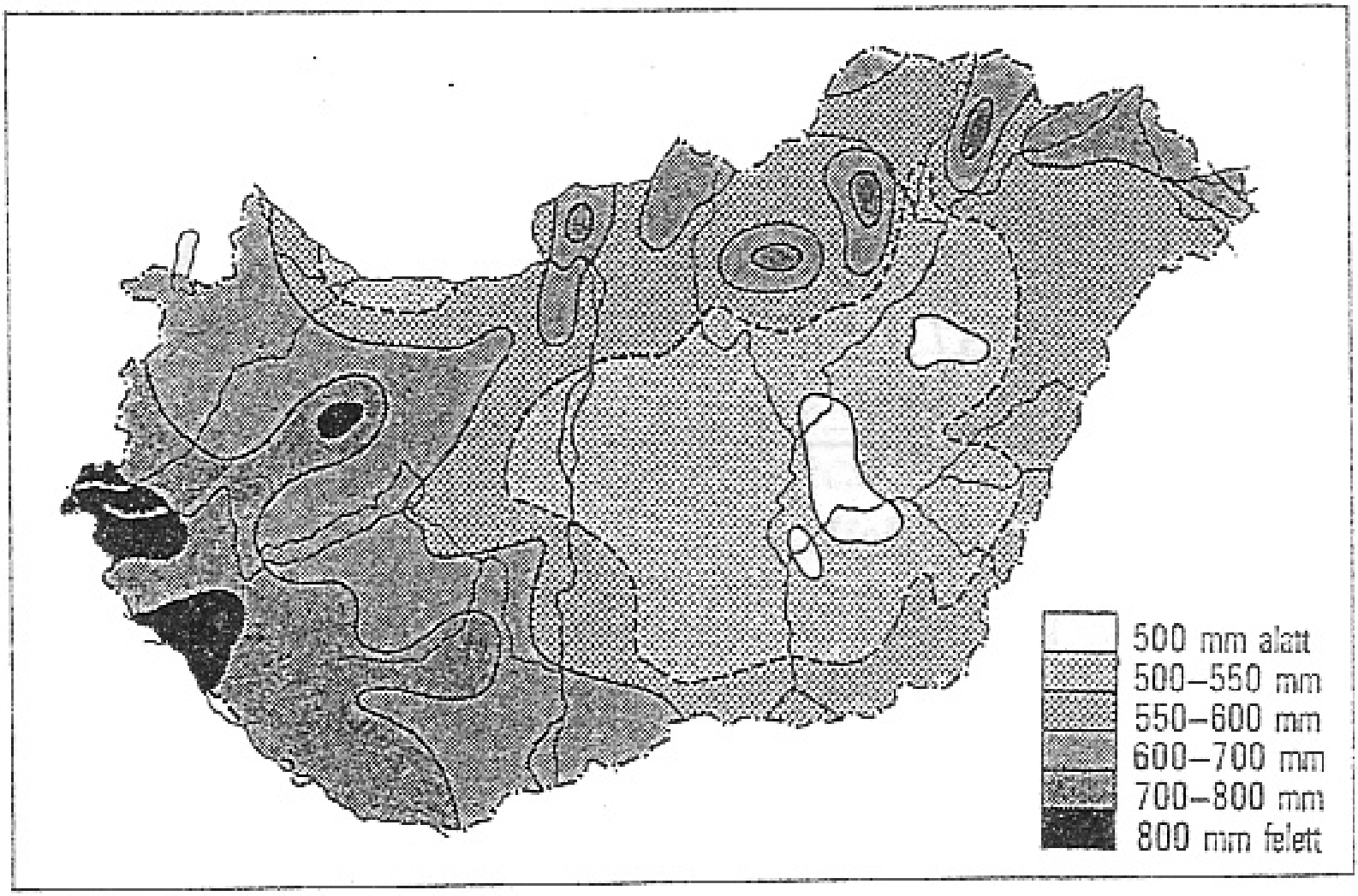
M.magyaróvár		Zalaegerszeg		Pécs		Budapest	
1900	947	1940	1134	1896	1204	1937	989
1903	898	1937	1102	1881	1117	1915	941
1937	862	1895	1058	1895	1064	1882	896
1939	877	1882	956	1897	1061	1955	895
1888	802	1966	944	1889	1011	1881	894

Kecskemét		Szeged		Túrkeve		Nyíregyháza	
1881	843	1940	867	1882	888	1966	857
1910	826	1897	788	1944	844	1980	837
1896	818	1919	785	1881	837	1915	821
1915	738	1937	774	1940	811	1919	787
1940	720	1915	772	1883	789	1940	786

The lowest annual precipitation amounts
in Hungary, mm, 1881-1992

M.magyaróvár		Zalaegerszeg		Pécs		Budapest	
1989	426	1917	532	1990	458	1990	415
1908	407	1953	505	1957	446	1986	414
1978	407	1971	502	1921	440	1961	400
1917	387	1908	496	1983	439	1973	400
1932	327	1932	449	1971	397	1992	363

Kecskemét		Szeged		Túrkeve		Nyíregyháza	
1935	386	1961	363	1934	391	1962	364
1890	361	1973	350	1973	391	1917	360
1946	360	1917	347	1992	388	1904	359
1982	337	1983	347	1917	351	1972	356
1983	334	1977	339	1983	342	1986	353

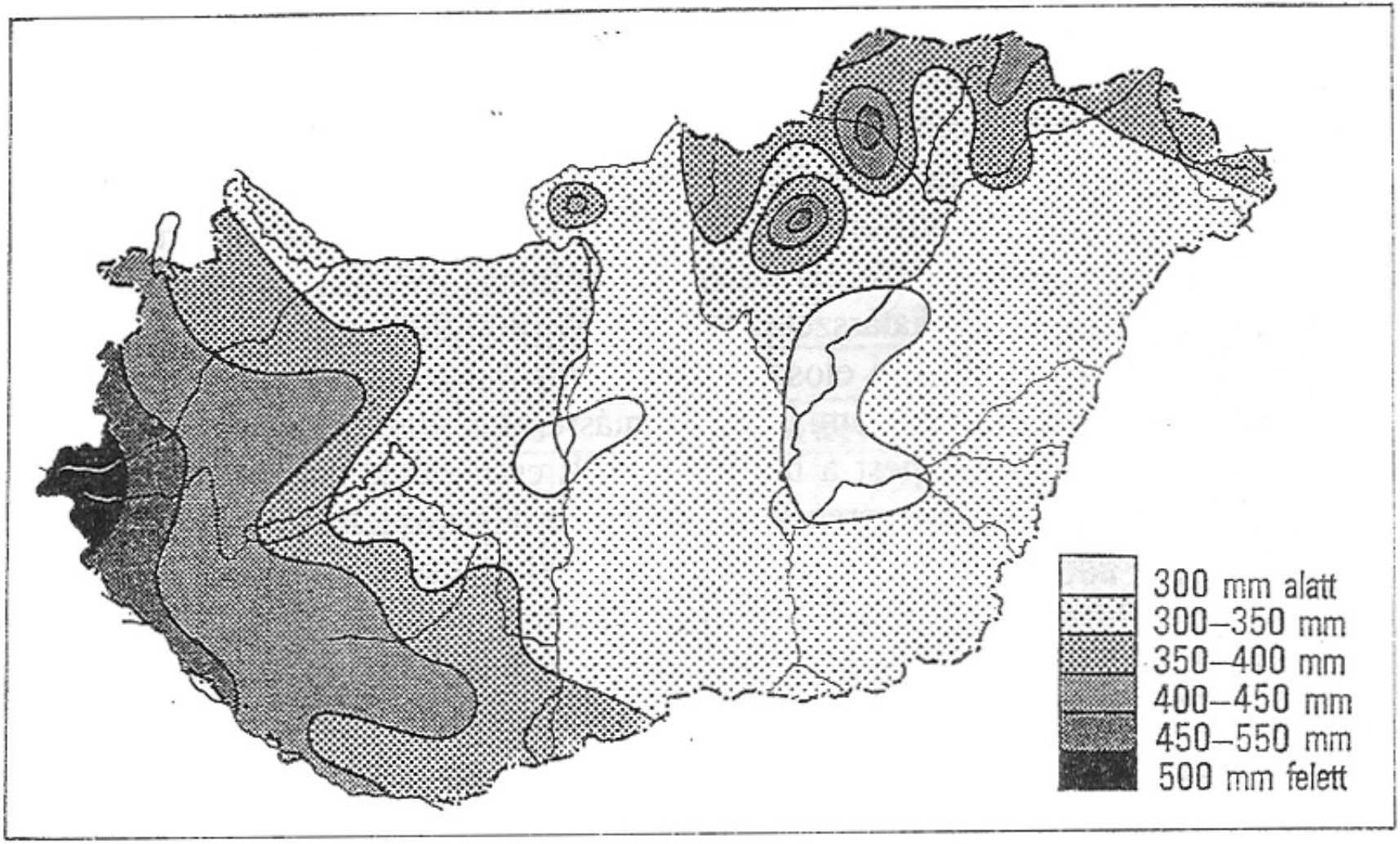


Geographical distribution of the mean annual precipitation amount in Hungary, mm

- The spatial distribution of precipitation is mainly influenced by the combined effect of the increasing distance from the ocean (weakening oceanic effect) and the topography.
- In Dunántúl area, parallel to the weakening oceanic effect, mean annual precipitation total decreases from 800 mm to 550 mm, from south-west to north-east direction.
- To the east from the Danube River, in Alföld area mean annual precipitation total decreases concentrically from 550 mm to 500 mm, which can be traced back to the basin character of Alföld area.
- In Hortobágy and Triple-Körös areas 480-500 mm precipitation falls per year, while in Szatmár-Beregi-Plain this quantity is up to 600 mm.
- There is two-fold difference in the annual pecipitation amount betwen the central part of Alföld (Great Plain) and West Dunántúl.
- In most parts of the medium-high mountains of Hungary total annual precipitation generally exceeds 600 mm.

- Mountains in Hungary, due to the orographic precipitation formation, show precipitation surplus compared to plains.
- On average, an increase of 100 m above sea level is associated with around 50 mm precipitation growth per year.
- However, the anomaly cannot be uniformly detected in the mountains.
- This precipitation growth is the strongest in the luv side of the mountains, perpendicular to the prevailing wind direction (High-Bakony). However, in the opposite (lee) side negatíve anomaly may also occur (Börzsöny Mountain).

Height (m)	100	150	200	300	400 mm
Alföld	545	560	-	-	-
Kisalföld	580	620	-	-	-
Dunántúl	650	670	690	700	720
Északi-hegység	545	675	590	650	700
average	560	600	650	680	710



Geographical distribution of the mean precipitation total (mm) during the growing season in Hungary

- Precipitation amount fallen within the growing season (between April and September) is important in agricultural point of view.
- On national average, this amount is 55-65% of the annual total precipitation.
- Regional distribution of this quantity is similar to that of the annual total precipiattion. However, we should note that the central part of Alföld area (Great Plain) is extremely dry.
- Although the growing season is wetter than the winter half-year, rainfall amount in the growing season only with the water amount coming from snow melting is sufficient for vegetation.

Frequency of precipitation amounts exceeding different threshold values

- Besides quantity, the intensity (i.e. precipitation fallen during a unit time: hour, minute; in other word hour- or minute- ntensity) is also an important feature of precipitation).
- This is an important parameter, in respect of the efficacy of infiltration and soil erosion processes.
- Water of an intense rainfall infiltrates less, and the impact of its raindrops of high kinetic energy strongly destroy soil aggregates.
- It is calculated on ombrograph data. Days with precipitation amounts exceeding the following thresholds are used to be classified: cs > 0.1 mm, cs > 1 mm, cs > 5 mm and cs > 10 mm (cs: daily precipitation amount).
- Intensity in the most heaviest showers may reach even 1-3 mm/minute; however, the more frequent quiet rains provide 1 mm/hour precipitation.

1) Landslides occur in those areas, where clay or marl layers alternate with permeable layers.

Cholnoky: ⟶ lanslide → slip, its part is „hepe”, often with hepe-lake;

E.g. Mezőség, or the Garden of Dragons (Szilágy county) in Transylvania;

Jenő Cholnoky: The Earth and it life, volume 6;
volume 6: Geography of Hungary, page 492;

„When I showed my students the slips, I warned them, that they can be immediately recognized on the rough surface (surface with „hepe-hupa”). Transylvanian boys are not familiar with this word and one jokingly said that surely those sleep hills were the „hupa” and the hollows between them the „hepe”. The joke was successful, because sence then these forms have been named so, and recently these morphological terms have been generally accepted; namely, hupa is a hill generated by slips and hepe is a hollow. Water frequently accumulates in the latter forms: this is the hepe-lake.”

2) Landslides occur in those areas, where steep loess surfaces are found (e.g. in the eastern basin of Lake Balaton, or along the right bank of the Danube, as Dunaföldvár, Paks and Dunaszekcső).

The loess pores are easily saturated with water $\longrightarrow$ loess walls may burst off the steep loess surfaces;

In wet years the damage could reach 10 billion HUF;

In loess areas the collapse of loess walls can be prevented with contructing of slopes and installing of soil-bounding vegetation;

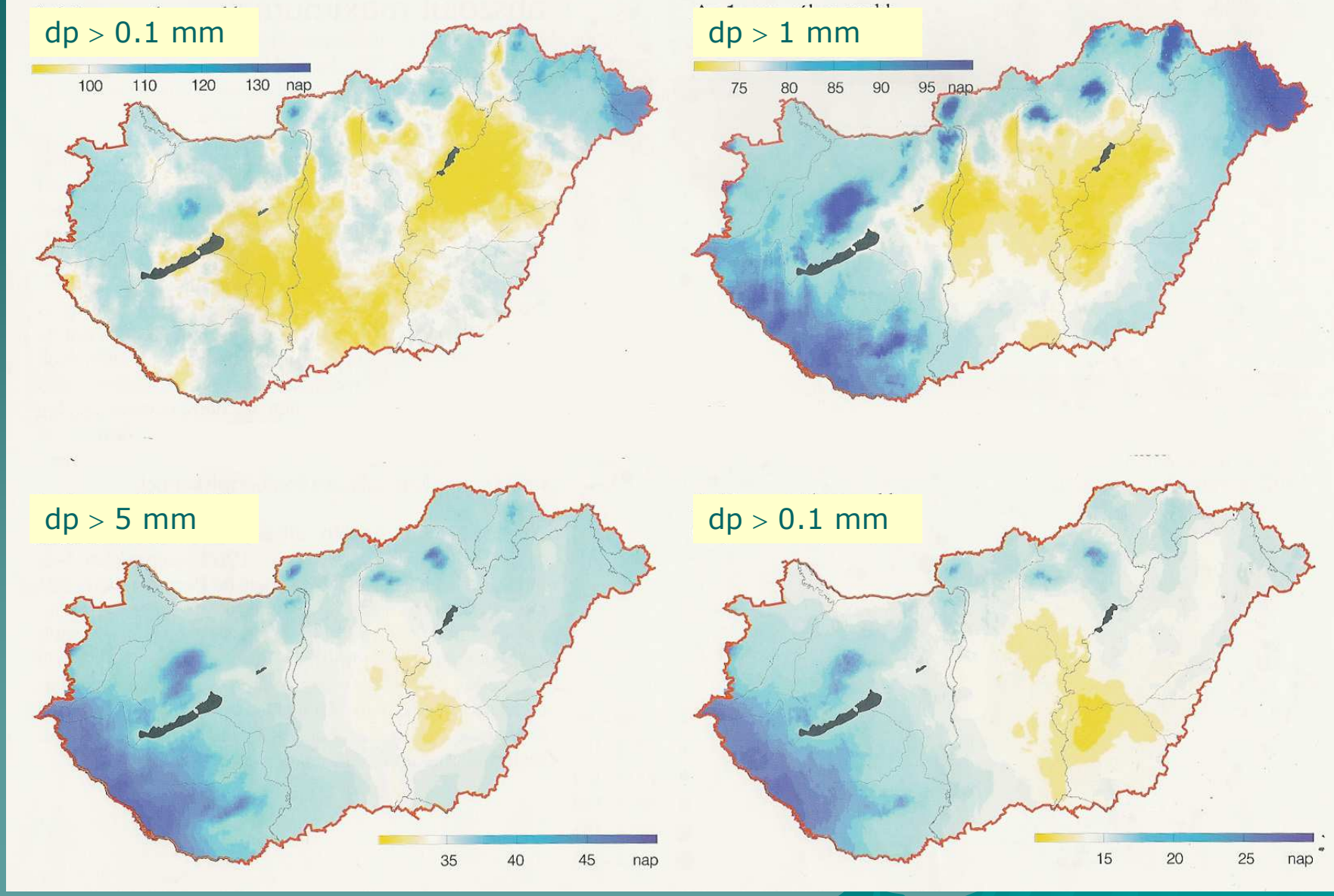
Examples:

- the tunnel in Balatonakarattya is approaching towards the Lake Balaton by 1-2 cm per year,
- the railway station in Balatonvilágos is slipping otwards the lake Balaton,
- Hollóháza, Ercsi and Rácalmás are also struggling against hillside movements.

Professional recommendations:

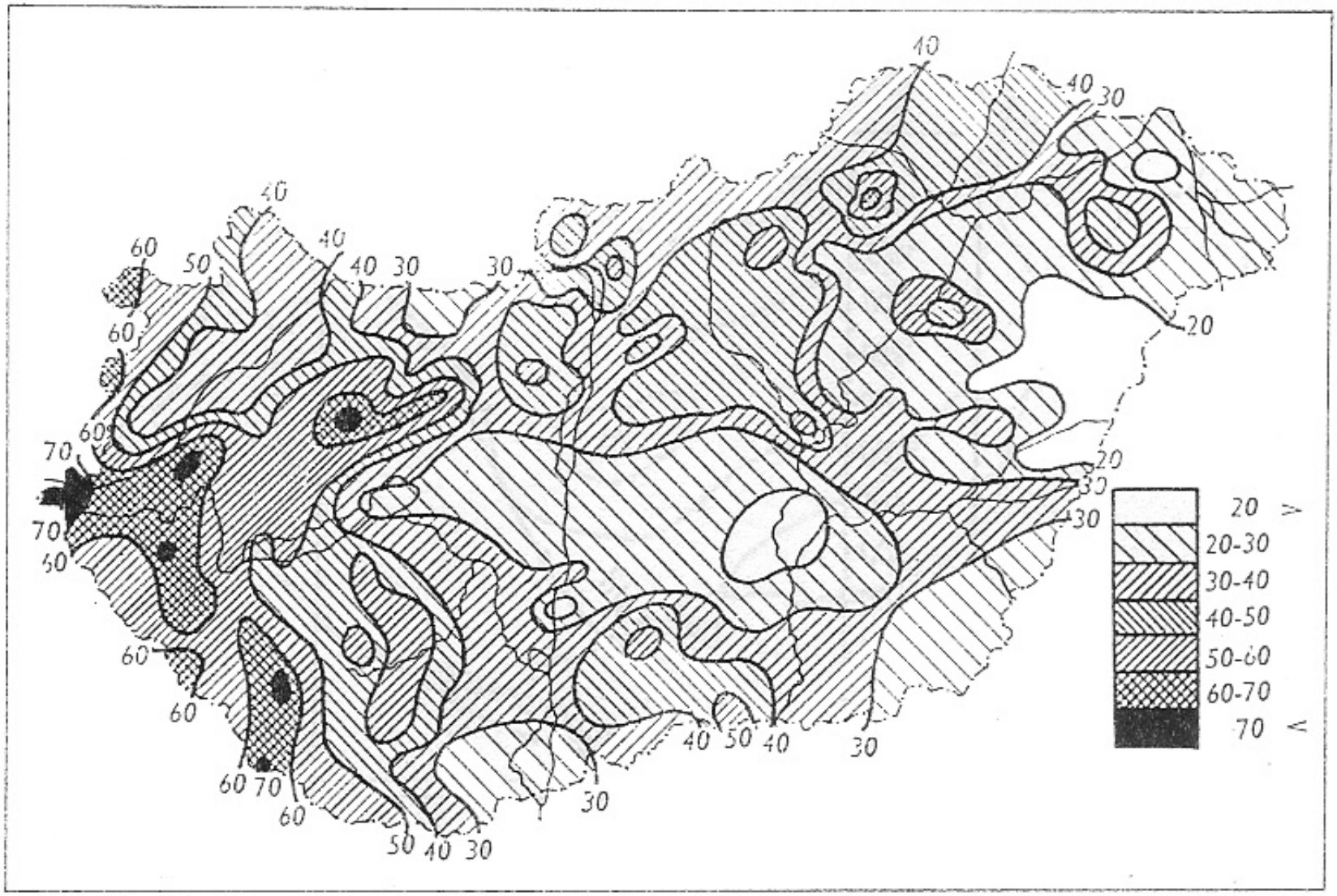
- construction works are prohibited within the distance from the loess that equls with the height of the loess wall;
- geological survey of the settlements, to determine areas being under prohibition from building permit;
- insulation of the sewing system (in the absence of this, will cellars collapse.

Annual number of days with daily precipitation (dp) exceeding different thresholds



- The number of rainy days is not closely related to the spatial distribution of the annual total rainfall. In the middle, dry parts of Alföld area (Great Plain) the annual number of rainy days is little (around 110 days). At the same time, the most precipitation falls at altitudes higher than 700 m above sea level and in the Szatmár-Beregi Plain (135 days).
- Bigger rainfalls are closely associated with the topography.
- Precipitation above 1 mm per day occurs on less than 75 days and 95-100 days per year in the middle parts of Alföld (Great Plain) area and in West-Dunántúl, respectively.
- Precipitation above 5 mm per day occurs 35-40 days and 45-50 days per year in the middle parts of Alföld (Great Plain) area and in West-Dunántúl, respectively.
- Precipitation above 10 mm per day occurs $<$ 15 days per year in the middle parts of Alföld (Great Plain) area and $>$ 25 days per year in West-Dunántúl, respectively.

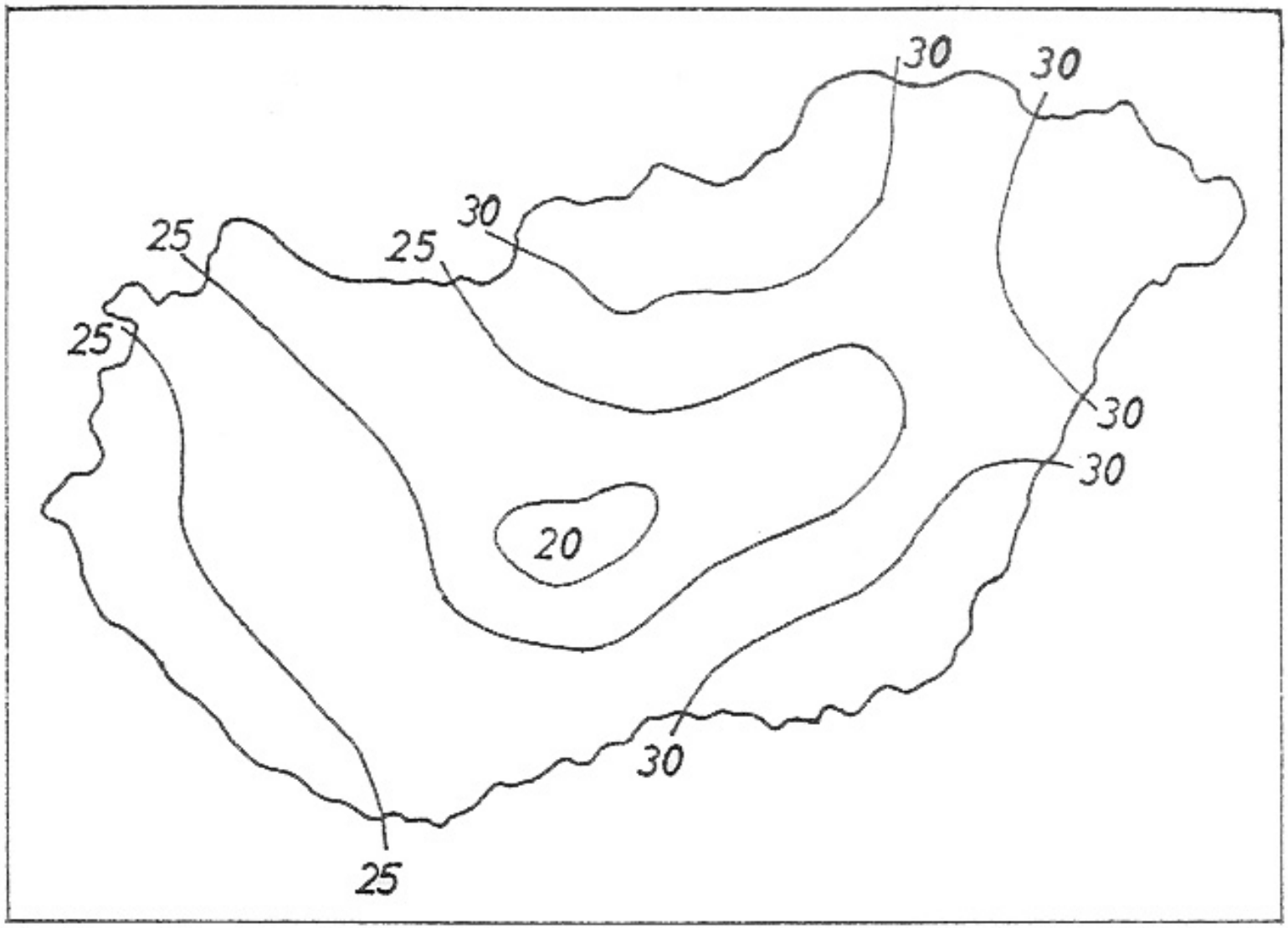
- 75% of the total duration of the precipitation is below 1 mm/hr of rainfall intensity, resulting in 30% of the total precipitation amount.
- Moderately-intensity rainfall (1-5 mm/hr) takes 22% of the annual duration of precipitation, resulting in 50% of the total precipitation amount!
- High intensity (above 5 mm/hr) rainfall occurs only during 2% of the total rainy days; however, this involves 20% of the total annual rainfall amount!
- Accordingly, the significance of the medium- and high intensity rainfall facilitating erosion is outstanding.
- A thunderstorm origin erosion risk index is used to evaluate the soil erosion impact of frequent high intensity precipitation.



Thunderstorm origin erosion risk index (indices)
in Hungary

Extreme high precipitation amounts for Hungary (rainfall intensity):

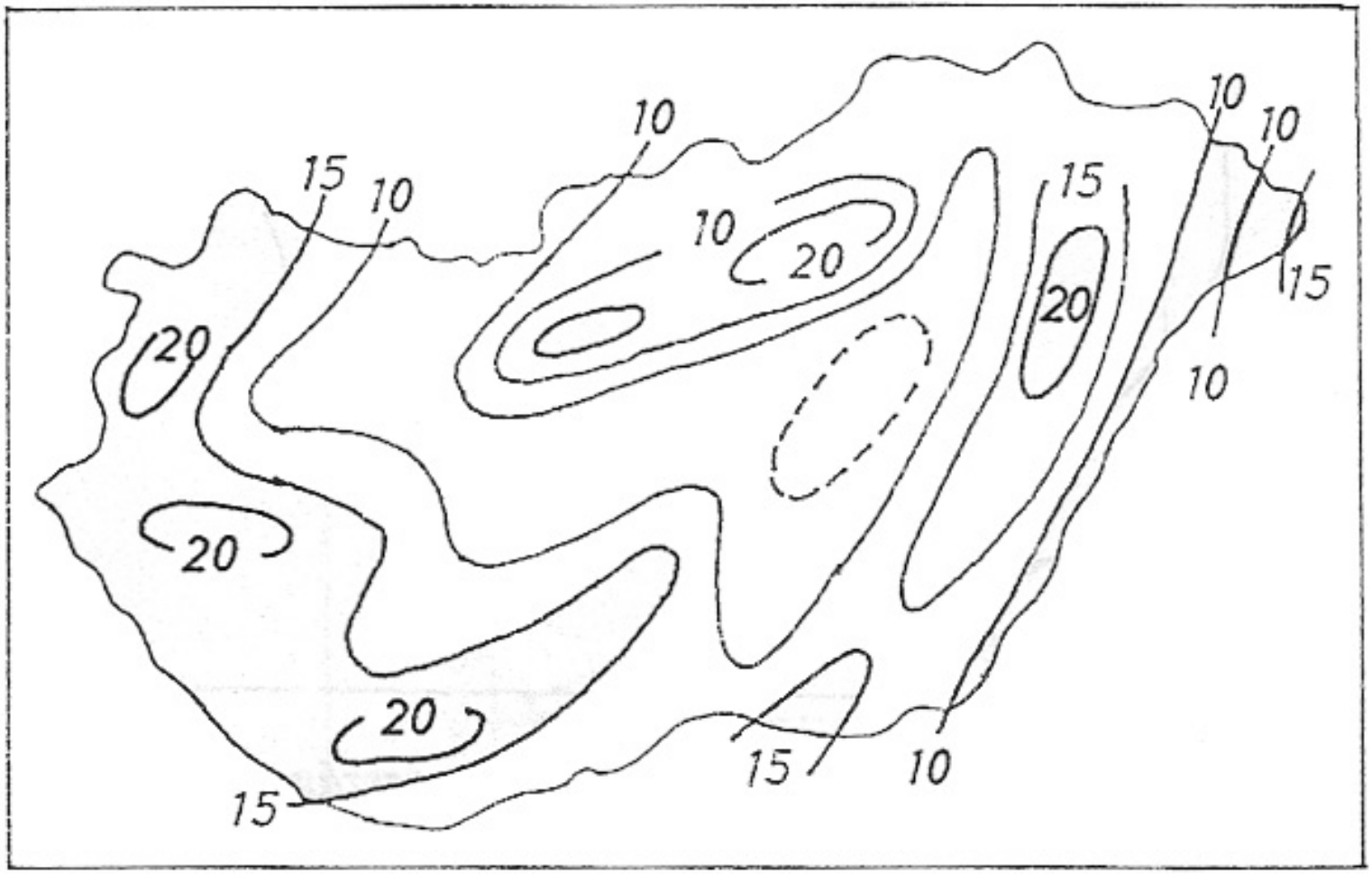
Duration, minute	Amount, mm	Location	Duration	Amount, mm	Location
1 min	5	Budapest	1 hour	80	Zsombok
3 min	12	Somogyszi.	2,5 hour	125	Téglás
5 min	21	Misinatető	4 hour	132	Páty
8 min	37	Nagykáta	1 day	260	Dad
15 min	54	Vasvár	1 month	444	Dobogókő
20 min	74	Mezőberény			



Mean number of thunderstorm days in Hungary

Thunderstorms and hails

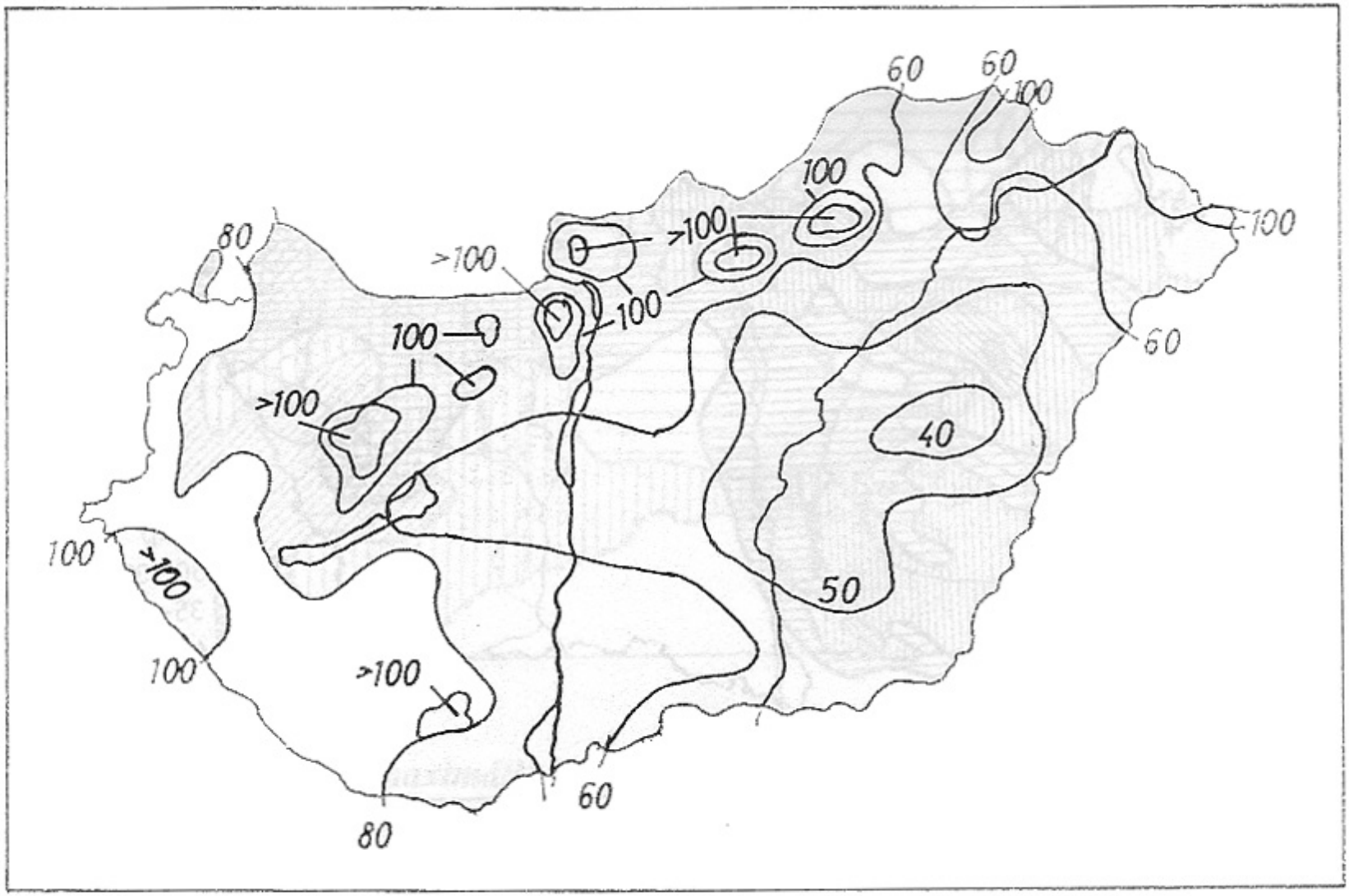
- Thunderstorm is on eor more electrical discharges, accompanied with flash of light and sharp or rumbling sound. In all cases it is related to the formation of Cb, furthermore usually strong gusty winds and heavy shower and hail.
- Thunderstorms occur most ferquently in Mátra- and Dunazug Mountains, in South-east Alföld (Great Plain) area and in Szatmár-Beregi Plain (above 30 days/yr).
- The lowest frequency of thunderstorms occurs in the middle parts of Alföld (Great Plain) area (below 20 days/yr).
- Thunderstorms frequently involve hails, if in the top of the thunderstorm cloud the the tmeperature is well below 0°C and the upwelling is extremely strong.
- The most hail occurs in July (20 occasions as average of many years), while the fewest in December (0.4 occasions as average of many years).
- Hails occur in Hungary along so called „hail paths”; namely, Mátra- and Bükk Mountains, Kemeneshát, Villányi Mountain and Hajdúhát.



Mean number of days with hail in the growing season in Hungary

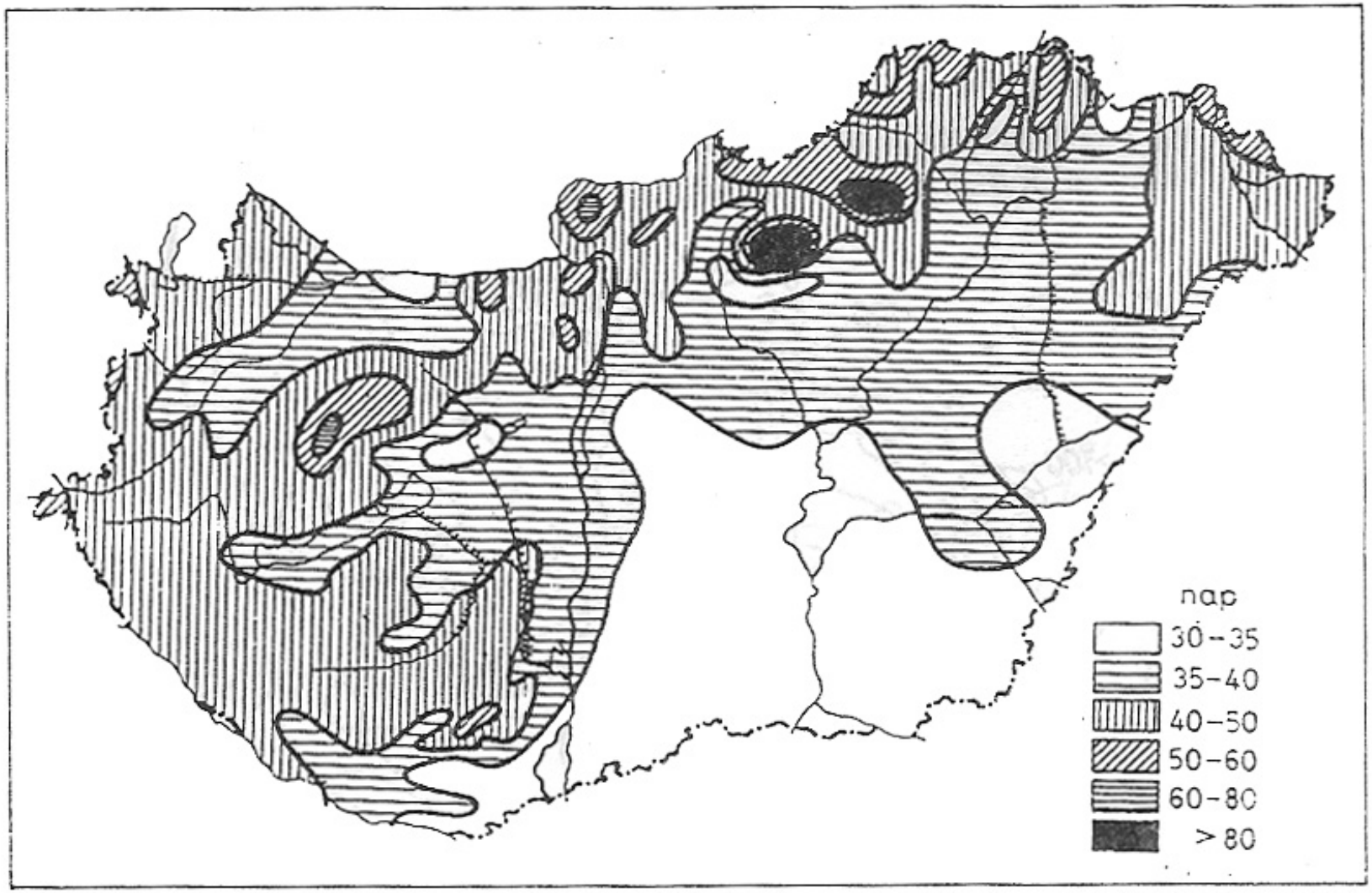
Snow and snow cover

- A specific feature of the climate of Hungary is that snow is falling even in the mildest winters, although its amount varies between wide ranges from year to year.
- in Alföld (Great Plain) area it is snowing on average 18-22 days per year. It is snowing 25-30 days in Dunántúl and the hilly aeras, 30-40 days in the mountains and 50-60 days above 700 m height from the sea level.
- The water equivalent precipitation fallen in the form of snow is between 40-170 mm on average. At the same time, above 400 m height from the sea level it exceeds 100 mm everywhere.
- In West-Dunántúl area, the milder winters result in on average 80-120 mm water equivalent snow amount per year (the effect of Genoa cyclone).
- Alföld (Great Plain) area characterized by harsh winters provides on average a mere 40-60 mm water equivalent snow amount per year.
- The share of snow from the annual precipitation amount in Alföld (Great Plain) area is on average 7-10%, in South-west-Dunántúl 10-15%, while in the mountains 15-20%.



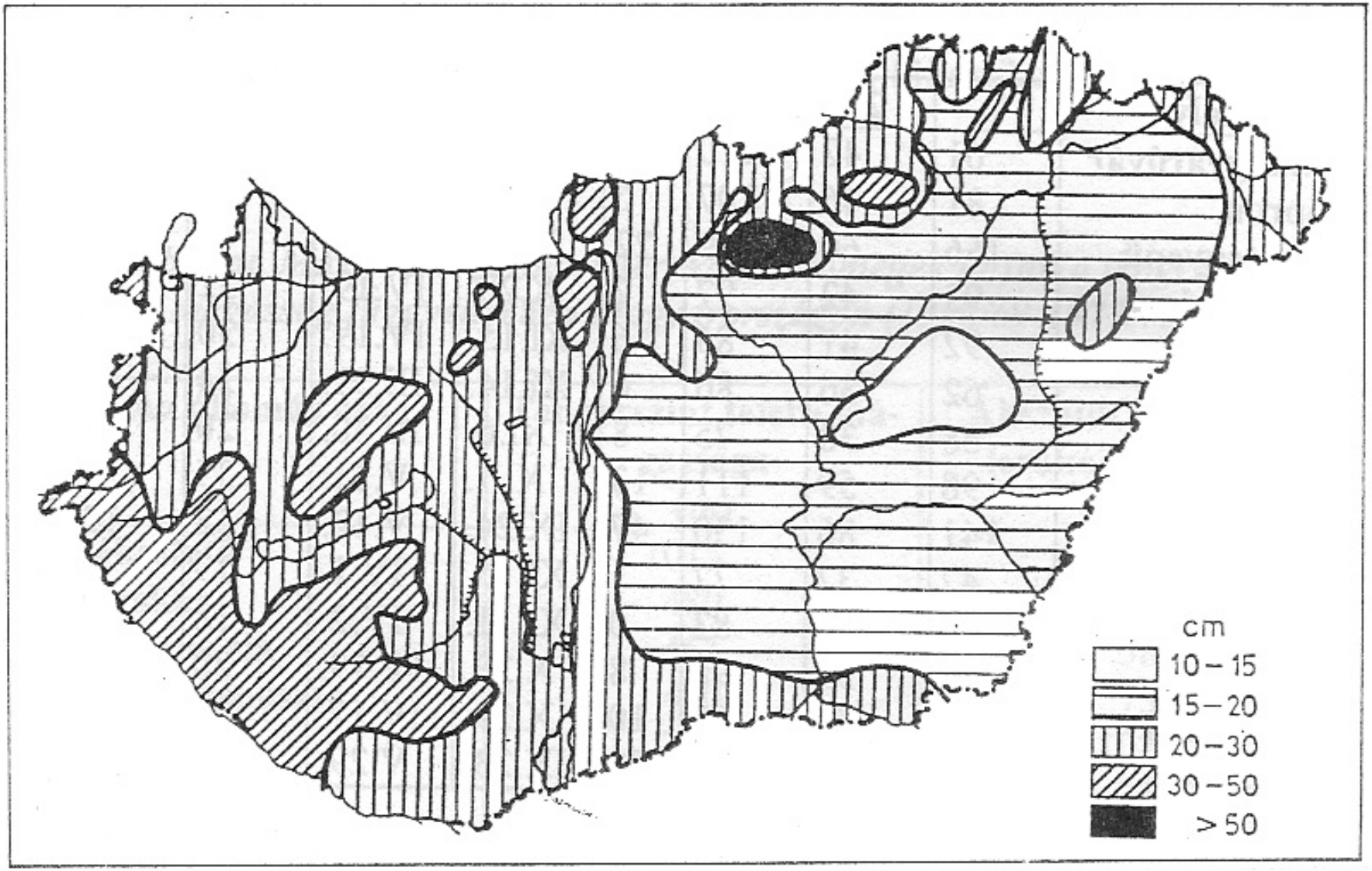
Mean annual amount of the water equivalent snow in Hungary

- After snowfall, if the tempertatureremains permanently below 0°C, the snow cover is retained for longer or shorter periods of time. The days when the surface is covered by at least 1 cm thick complete snow cover, are called snow-covered days.
- The least number of snow-covered days occur in the middle parts of Alföld (Great Plain) (30-35 days), where the amount of snow fallen is scarce.
- The number of snow-covered days in the most parts of Dunántúl area is between 40-45 days, due to the more snow and despite the higher average temperature in January.
- In the medium-high mountains the number of snow-covered days exceeds 50 days, however above 700 m from the sea level 100-120 snow-covered days occur.
- In Dunántúl Medium-high Mountain, every 100 m increase in the height from sea level involves 9 days increase in snow-covered days.
- In some winters no complete snow cover occurs in Alföld (Great Plain) area, while in other winters snow remains there through 80-100 days.



Mean annual number of the snow-covered days in Hungary

- Snow-cover thickness is also an important climate parameter. By averaging maximum snow-cover thicknesses of different winters, we obtain mean maximum snow-cover thickness.
- This value is about 15-20 cm in the cold and snowy Alföld (Great Plain) area.
- At the same time, this value is 25-40 cm in Dunántúl-Hills.
- In the medium-high mountains and in the edge of West-Hungary this value is 30-50 cm.
- Its value exceeds 50 cm above 500 m height from sea level.
- Every 100 m increase in the height from sea level involves 9 cm increase in the national value of the mean maximum snow-cover thickness.
- In Alföld (Great Plain) area there are winters when there is no measurable thickness of snow-cover and, at the same time, also winters when a complete, 60-80 cm thick anow-cover occurs. The national extreme thick snow cover is 151 cm (February 1947, Kőszeg-Stájerházak)



Mean maximum snow-cover thickness (cm) in Hungary

Hoar

- Micro-precipitation: it is formed when water vapour condenses on the surface and different objects below 0°C.

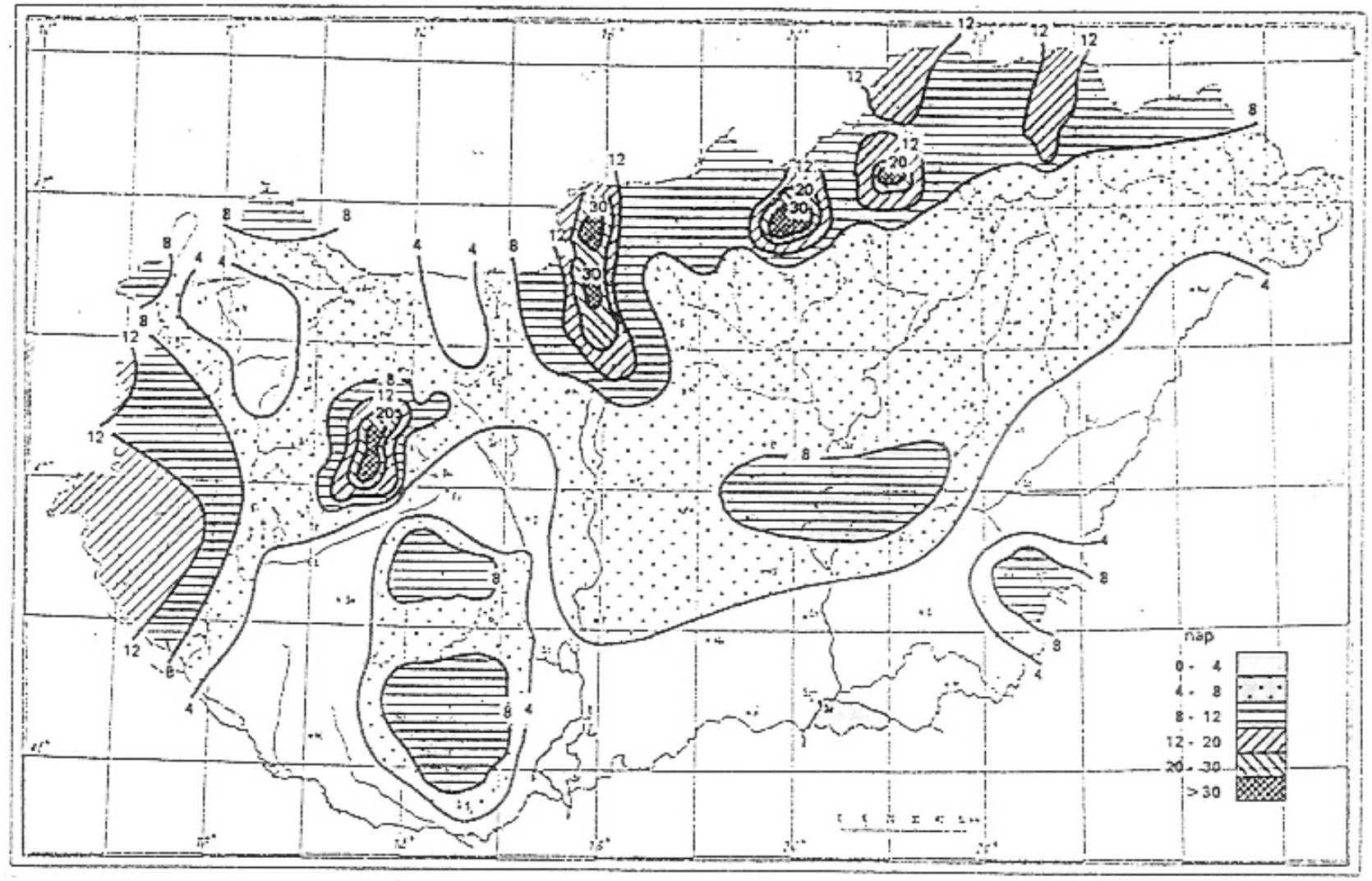
Rime

Rime

- Rime is a type of micro-precipitation condensed and deposited on branches of trees or edges of different objects below 0°C temperature from flowing mild and humid air and forming ice needles.
- Due to making a significant overload, they may break off branches of trees and overhead cables.
- Due to its potential severe damage, this is the only regularly measured micro-precipitatoion. In Hungary, a rime measuring network has been working since the winter of 1967/68.
- The most rimy areas in Hungary are the mountains, where the mean annual number of rimy days exceed 30 days, while in Alföld (Great Plain) area this value is only 4-8 days.
- A signfiicanzt amount of rime may be deposited even in less rimy areas.

Maximum deposited rime (g/m) in the function of the height above sea level in Hungary, 1968-69 – 1977-78

station	Height above sea level (m)	Mass of the absolute maximum deposition (g/m)
Kékestető	1015	2160
Hárskút	480	1020
Csőszpuszta	461	584
Nagyírtáspuszta	420	738
Isztimér	267	1022
Szentgotthárd	226	310
Szombathely	224	340
Gödöllő	218	316
Tihany	170	600
Debrecen	111	768



Mean annual number of the rims days in Hungary

Always look on the bright side of things!

We finished for today, goodbye!

ямарваа нэг зүйлийн гэгээлэг
талыг нь үргэлж олж харцгаая

өнөөдөртөө ингээд дуусгацгаая, баяртай

让我们总是从光明的一面来看待事物吧！

今天的课程到此结束，谢谢！

دعونا ننظر دائما إلى الجانب المشرق من الأشياء!

انتهينا لهذا اليوم، وداعا!